Dynamical Evolution of Dense Stellar Systems
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How mass segregation in star clusters can change the observed SFHs of galaxies

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Poster n. 1

Abstract.

Galaxies' SFHs can be determined from the ages of their star clusters. Mass segregation causes the low-mass stars, preferentially found in the outer parts of the cluster, to be easiest stripped off by tidal effects, and hence also has an impact on the integrated cluster photometry. The MF of a cluster evolves due to three effects:

(a) the evolution of massive stars

(b) early tidal effects reduce the MF independently of the stellar mass

(c) later, tidal effects preferentially remove the lowest-mass stars from the cluster.

Results: During the first 40% of the lifetime of a cluster the cluster simply gets fainter due to the general loss of stars. Between 40 and 80% of its lifetime the cluster gets bluer due to the loss of low-mass stars, resulting in an underestimate of the age of clusters from standard cluster evolution models (0.15-0.5 dex). After 80% of the total lifetime of a cluster it will rapidly get redder, . This is because stars at the low-mass end of the main sequence, which are preferentially lost, are bluer than the AGB stars dominating the light at long wavelengths, resulting in an age overestimate. The changes in the colour evolution of unresolved clusters due to the preferential loss of low-mass stars will affect the determination of the SFHs of galaxies.

The Effects of Binary Stars on the Evolution of Globular Clusters

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Poster n.2

Abstract. I will discuss the influence of binary stars on globular cluster evolution, especially their role in late core collapse and post collapse evolution. Theoretical models of two-component globular clusters are designed in such a way that we can examine the effects 3-body interactions with binary stars in the core of the cluster have on the overall evolution. I will discuss these models and the conclusions found from them.

Slow evolution of a system of satellites induced by dynamical friction

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Poster n.3

Abstract. Elliptical galaxies often host significant systems of globular clusters. The properties of such systems

change with time because of stellar evolution, stellar dynamical effects inside the clusters, and tidal interactions between each globular cluster and the galaxy. In addition, such systems can evolve because of the dynamical friction felt by the individual globular clusters while moving through the host galaxy.

Here, by means of N-body simulations, we focus on the evolution induced by dynamical friction by considering a system of rigid satellites initially placed on a quasi-spherical shell. With respect to the study of friction on a single heavy object, this configuration represents an intermediate step in the direction of studying a realistic three-dimensional distribution of globular clusters, with the advantage of defining a dynamical problem in which quasi-spherical symmetry is preserved in the course of evolution and of testing to what extent dynamical friction can be thought of as a basically local process. We consider a variety of such shell configurations, characterized by different mass and phase space properties, and investigate their evolution in realistic galaxy models, characterized by high density concentration and by radially-biased pressure anisotropy [1].

As a result of the exchange of energy and angular momentum with the otherwise collisionless stellar system, shells of satellites slowly fall towards the center of the host galaxy without reaching it. During the fall, the shell decreases its thickness and after several dynamical times it reaches a quasi-equilibrium configuration where the number of satellites on eccentric orbits has increased. The host galaxy responds to the infalling shell with a decrease of its density concentration and of its pressure anisotropy in the radial direction [2].

[1] Arena, S.A. & Bertin, G. 2007, A&A, 463, 913

[2] Arena, S.A. 2007, Ph.D. Thesis, Universita gli Studi di Milano, Milano

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The formation and evolution of massive and very massive stars in dense stellar systems

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Poster n.4

Abstract. The early evolution of dense stellar systems is governed by massive single star and binary evolution. Core collapse of dense massive star clusters is unavoidable and this leads to the formation of very massive objects, with a mass up to 1000 Mo and even larger. When these objects become stars, stellar wind mass loss determines their evolution and final fate, and decides upon whether they form black holes (with normal mass or with intermediate mass) or explode as a pair instability supernova. I will discuss current ideas about the evolution of massive stars and binaries, with special emphasis on the evolution of very massive stars. A convenient evolutionary recipe for the very massive stars is presented that can readily be implemented in an N-body code. Finaly, using an N-body code that includes the massive and very massive star evolutionary updates, we discuss a) the effects of dynamics on the early evolution of the massive binary frequency in dense stellar systems and b) the formation of intermediate mass and stellar mass black holes.

Study of the Nearest Open Clusters and the Associated Moving Clusters by Numerical Simulations

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Poster n.5

Abstract. In our previous papers, we showed that at the final phases of the dynamical evolution of an open cluster, an extended population of stars elongated along its Galactic orbit, the stellar tail of the cluster, is formed. The tail stars that escaped from the cluster at different times move in a common orbit with low relative velocities. Experiencing a weak interaction with Galactic field stars, these objects, the relics of open clusters, can exist for a fairly long time. In this paper, we investigate the structures of such stellar tails in the nearest open clusters: Hyades, Pleiades, Praesepe, Alpha Persei, Coma, IC 2391, and IC 2602. To this end, we performed

several numerical simulations of the dynamical evolution of these clusters in the tidal field of the Galaxy. Our computations of the dynamical evolution were based on known cluster age estimates and real Galactic orbits. The initial conditions were chosen in such a way that the parameters of the simulated clusters corresponded to their observed parameters. As a result, we obtained models of the stellar tails for the nearest open clusters and estimated such parameters of the tails as their sizes, densities, locations relative to the solar neighborhood, and others.

The binary fraction of NGC 6397

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Poster n.6

Abstract. We have used a 126-orbit integration with HST to study the globular cluster NGC6397, obtaining an image of a single ACS field 5' from the core. We also obtained WFPC2 parallels of the core. Using the high-quality photometry in the outer field we studied the distribution of stars in the color-magnitude plane, and determined the binary fraction to be 0.012 +/- 0.002. Similarly, we constrain the binary fraction in the core to be 0.15 +/- 0.01. Constraining the binary fraction in the cluster core and outskirts simultaneously sets a rigorous hurdle for theoreticians attempting to accurately model globular clusters.

Millisecond pulsars around intermediate–mass black holes in globular clusters

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Poster n.7

Abstract. Globular clusters are expected to be breeding grounds for the formation of single or binary intermediate–mass black holes (IMBH) of $\sim> 100\,m_\odot$, but a clear signature of their existence is still missing. In this context, we study the process of dynamical capture of a millisecond pulsar (MSP) by a single or binary IMBH. It is found that [IMBH,MSP] binaries form over cosmic time in a cluster, via encounters of wide–orbit binary MSPs off the single IMBH, and at a lower pace, via interactions of (binary or single) MSPs with the IMBH orbited by a cluster star. The formation of an [IMBH,MSP] system is strongly inhibited if the IMBH is orbited by a stellar mass black hole (BH). The [IMBH,MSP] binaries that form are relatively short-lived, $<\sim 10^{8-9}$ yr, since their orbits decay via emission of gravitational waves. The detection of an [IMBH,MSP] system has a low probability of occurence, when inferred from the current sample of MSPs in GCs. If next generation radio telescopes, like SKA, will detect an order of magnitude larger population of MSP in GCs, at least one [IMBH,MSP] is expected. Therefore, a complete search for low-luminosity MSPs in the GCs of the Milky Way with SKA will have the potential of testing the hypothesis that IMBHs of order $100\,m_\odot$ are commonly hosted in GCs.

Unveiling the core of the Globular Cluster M 15 in the far-ultraviolet

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Poster n.8

Abstract. We present an analysis of our deep far- (FUV) and near-ultraviolet (NUV) photometry of the core region of the dense globular cluster M 15. Our $FUV-NUV$ colour-magnitude diagram is the deepest one presented for a globular cluster so far, and shows all hot stellar populations expected in a globular cluster, such as horizontal branch stars, blue stragglers, white dwarfs, cataclysmic variables and even main sequence stars. The main sequence turn-off is clearly visible and the main sequence stars form a prominent track that extends at least two magnitudes below the main sequence turn-off. We compare and discuss the radial distribution of the various stellar populations that show up in the FUV. We search for variability amongst our FUV sources and tentatively classify our variable candidates based on an analysis of the UV colours and variability properties. We find that RR Lyraes, Cepheids, and SX Phoenicis exhibit massive variability amplitudes in this waveband (several mags).

A Post-Newtonian Treatment of Relativistic Binaries in Star Clusters

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Poster n.9

Abstract. Stellar-mass compact object binaries provide sources of background gravitational radiation observable by the current VIRGO and LIGO gravitational wave detectors. Since dense star clusters have high binary fractions that can harden efficiently and reach high eccentricites through dynamical interactions, such environments should produce a strong signal for VIRGO and LIGO. In order to produce proper templates for gravitational waves emitted by such clusters, accurate statistics both on the orbital parameters of such binaries and their number and location at different stages of cluster evolution must be produced. We approach this problem by implementing a Post-Newtonian treatment of general relativity in the direct N-body code NBODY6++ and studying the evolution of the binary population in order to extract the neccessary parameters. We will present preliminary results on the statistics of relativistic binaries in star clusters with simulations based on the Kyoto-II experiment.

Modelling the Tidal Tails of NGC 5466

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Poster n.10

Abstract. The study of sub-structures in the stellar halo of the Milky Way has made a lot of progress in recent years, especially since surveys like the Sloan Digital Sky Survey became available. In this paper we focus on the newly discovered tidal tails of the Galactic globular cluster NGC 5466. By means of numerical simulations we reproduce the tidal tails and hereby finding a possible progenitor of NGC 5466 and analyse its stability. We show that disc shocking is the dominant process in the slow dissolution of NGC 5466. Furthermore we use the position

of the tails to verify the accuracy of the observationally determined proper motion. The proper motion has to be refined only slightly (within their stated error-margin) to match the location of the tidal tails.

Multiwavelength Survey for Binaries in the WIYN Open Cluster Study: First findings from NGC 188

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Poster n.11

Abstract. The WIYN open cluster study (WOCS) has been working to yield precise magnitudes in the Johnson-Kron-Cousins U, B, V, R, I system for all stars in the field of a selection of "prototypical" open clusters. Additionally, WOCS is using radial velocities to obtain orbit solutions for all cluster binary stars with periods of less than 1000 days. Recently, WOCS is being expanded to include the near-infrared J, H, K_s and mid-infrared ([3.6], [4.5], [5.8], [8.0]) photometry though new ground-based and Spitzer/IRAC observations. The combination of optical $UBVRI$, near-infrared JHK_s, and mid-infrared IRAC data allows us to identify *photometrically* non-equal mass binaries across a wide range of masses, especially for faint lower main sequence stars, where radial velocity surveys are prohibitive. The combination of up to 12 bands ($UBVRIJHK_s$ [3.6][4.5][5.8][8.0]) allow the fitting of two (or more) SEDs over a large wavelength range, which is needed to reliably identify the photometric binaries. We present the first preliminary comparison from our multi-band photometric study to that of the kinematics findings for binary frequency and spacial distribution for the prototypical old open cluster NGC 188.

Mass-Loss Timscale of Star Cluster in External Tidal Field

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Poster n.12

Abstract.

We investigate evolution of star clusters in steady external tidal field by means of N-body simulations. We followed several sets of cluster models whose strength and Coriolis's contribution of the external tidal field are different. We found that the mass loss timescale due to the escape of stars, $t_{\rm mloss}$, and its dependence on the two-body relaxation timescale, $t_{\rm rh,i}$, are determined by the strength of the tidal field. The logarithmic slope $[\equiv d\ln(t_{\rm mloss})/d\ln(t_{\rm rh,i})]$ approaches unity for the cluster models in weaker tidal fields. In our results, the slope 0.75 found by Baumgardt (2001) can be seen only in the cluster models with moderately strong tidal fields. We also found that stronger Coriolis force against others, produced by parent galaxy whose density profile is shallower, makes the mass loss timescale longer. This is due to the fact that a fraction of stars whose orbit are nearly regular increases as the Coriolis force becomes stronger.

The NGC 5128 Globular Cluster System

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Poster n.13

Abstract. We will present a review of our recent work on the globular cluster system of NGC 5128, the nearest giant elliptical galaxy. This includes imaging (with the CTIO 4m + MOSAIC, Magellan + MagIC and IMACS, and Gemini-S + GMOS) and spectroscopy (with the CTIO 4m + Hydra, Magellan + LDSS-2 and Gemini-S + GMOS). This extensive database provides a wealth of data to study the globular clusters. We will discuss the cluster census, resolution of clusters, their structural parameters, the metallicity distribution and initial spectroscopic results.

Building Blue Stragglers with Stellar Collisions

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Poster n.14

Abstract. In a dense stellar environment, such as a globular cluster, encounters between single stars or binary star systems can lead to the collision and merger of two stars. These merger remnants often stand out as blue stragglers. Understanding their formation and evolution is important for understanding the stellar population as well as the overall evolution of the cluster. Collisions between low-mass main sequence stars are relevant for the formation of blue stragglers in globular clusters. We have calculated the evolution of a large number of collision products formed at different times with different mass ratios for the progenitor stars. Our collision products are brighter and live relatively shorter than stars born with the same mass. Collisions between high mass stars are relevant for young clusters where they can form extremely massive stars through multiple collisions between high mass stars. We have performed the first systematic study of a grid of collisions between massive stars. Our calculations indicate that the lifetime and luminosity of these massive collision products depends sensitively on the mass ratio of the progenitor stars.

Clustered Star Formation in the Magellanic Clouds

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Poster n.15

Abstract.

The Magellanic Clouds (MCs) offer an outstanding variety of young stellar associations, in which large samples of low-mass stars (with $M \leqslant 1$ M$_\odot$) currently in the act of formation can be resolved and explored sufficiently with the *Hubble* Space Telescope. Recent results from observations with the *Advanced Camera for Surveys* of star forming associations in the MCs change dramatically the picture of these systems after the discovery of large numbers of such pre-main sequence (PMS) stars in their vicinity. The location of these stars in the color-magnitude diagram suggests continuous star formation, which lasts up to ~ 10 Myr, while their spatial distribution demonstrates the existence of significant substructure in the form of compact PMS clusters. We present these results and we discuss how these large numbers of low-mass PMS stars affect the dynamical behavior and the survival of their hosting associations.

Resonant relaxation near a massive black hole

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Poster n.16

Abstract. The orbits of stars close to a massive black hole are nearly Keplerian ellipses. Such orbits exert long term torques on each other, which lead to an enhanced angular momentum relaxation known as resonant relaxation. Under certain conditions, this process can modify the angular momentum distribution and affect the interaction rates of the stars with the massive black hole more efficiently than non-resonant relaxation. The torque on an orbit exerted by the cluster depends on the eccentricity of the orbit. In this paper, we calculate this dependence and determine the resonant relaxation timescale as a function of eccentricity. In particular, we show that the component of the torque that changes the magnitude of the angular momentum is linearly proportional to eccentricity, so resonant relaxation is much more efficient on eccentric orbits than on circular orbits. We use apply this result to eccentricity distribution of S-stars near the Galactric centre.

On the origin of hyperfast neutron stars

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Poster n.17

Abstract. We propose an explanation for the origin of hyperfast neutron stars [e.g. PSR B1508+55 (Chatterjee et al. 2005), RX J0822-4300 (Hui & Becker 2006; Winkler & Petre 2006), etc] based on the idea that they could be the remnants of a *symmetric* supernova explosion of a high-velocity massive star (or its helium core) which attained its peculiar velocity (similar to that of the neutron star) in the course of a strong three or four body dynamical encounter in the core of the parent young massive star cluster. Our proposal implies that the dense cores of young massive star clusters (located either in the Galactic disk or near the Galactic centre) could also produce the so-called hypervelocity stars (Brown et al. 2005) – the ordinary stars moving with a speed of $\sim 1\,000\,\mathrm{km\,s^{-1}}$.

Ultra-compact dwarf galaxies – more massive than allowed?

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Poster n.18

Abstract. The so-called ultra-compact dwarf galaxies (UCDs) are very massive ($10^6 M_\odot < M < 10^8 M_\odot$), old, compact stellar systems that were discovered in nearby galaxy clusters about a decade ago. Their nature is unknown yet. Maybe they are remnant nuclei of disrupted galaxies, or maybe they are merged stellar super-clusters formed in interacting/merging galaxies. Regardless of what UCDs actually are, some properties divide them from 'ordinary' globular clusters. The half-light radii of UCDs scale with luminosity/mass reaching ~ 90 pc for the most massive UCDs. Unlike for GCs, their densities within the half-light radii are not increasing with mass but stay at a constant level or even decrease. Thus UCDs are not that compact at all. In the luminosity-velocity dispersion diagram, UCDs deviate from the well defined relation of 'normal' GCs, being more in line with the Faber-Jackson relation of early-type galaxies. But, most surprisingly, measurements of dynamical masses of UCDs in Virgo and Fornax revealed that their mass-to-light (M/L) ratios cannot easily be explained with standard single stellar population models. UCDs show systematically higher M/L ratios than Galactic globular clusters. Is this an evidence for dark matter? Does tidal heating play a role? Or do the stellar populations of UCDs possess an unusual top-heavy initial mass function?

In my presentation I will summarizes our current knowledge of UCDs with special focus on the modelling of their surface brightness profiles, masses and mass-to-light ratios.

Dynamical Evolution of the Mass Function of the Galactic Globular Cluster System

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Poster n.19

Abstract. Using the most advanced anisotropic Fokker-Planck models, we calculate the evolution of the mass functions of the Galactic globular cluster system (GCMF). Our models include two-body relaxation, binary heating, tidal shocks, dynamical friction, stellar evolution, and non-circular cluster orbits. We perform Fokker-Planck simulations for a large number of virtual globular clusters and synthesize these results to study the relation between the initial and present GCMFs. We identify important factors in determining the evolution of the GCMF and estimate the most probable initial GCMF by comparing our calculations with current observations. We also discuss the differences between our results and previous studies.

The Formation of Contact Binaries

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Poster n.20

Abstract. Pribulla & Rucinski (2006) have shown that in a reasonably complete sample of 88 northern contact binaries, 52 ($59\% \pm 8\%$) show evidence of a third body. This high fraction raises the possibility that a third body is *necessary* for the formation of a very close binary. This may involve a combination of (i) Kozai cycles, (ii) tidal friction, and (iii) (for lower-Main-Sequence systems) magnetic braking.

Binaries and the dynamical mass of star clusters

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Poster n.21

Abstract.

The dynamical mass of a star cluster can be calculated analytically using Spitzer's equation, using the measured half-mass radius and line-of-sight velocity dispersion. When deriving the dynamical mass, one makes the assumption that all stars are single, which is known to be incorrect. Due to orbital motion, the measured velocity dispersion is overestimated, resulting in an overestimation of the dynamical mass. We present a detailed analysis of this effect, and show under which circumstances the presence of binaries can be ignored.

Mass Transfer in Binary Systems using SPH: Numerical Approach

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Poster n.22

Abstract.

Mass transfer in binary systems is an efficient way of creating exotic stars. In particular, blue stragglers, which are found above the main-sequence turn-off point in color-magnitude diagrams, are thought to have been created either by collisions or mass transfer in primordial binaries. The problem is that there doesn't seem to be any distinctive observational signature for either scenarios. In order to further investigate the formation scenarios of blue stragglers by mass transfer, we present preliminary work on our Smoothed Particle Hydrodynamics approach to this problem. More precisely, we want to model only the outer parts of the stars in order to get a much greater spatial resolution of the mass transfer flow itself. The inner boundary conditions are achieved by using the so-called ghost particles and by replacing the inner mass by a central point mass. Stability of this central point mass is crucial, and it is shown that we get reasonable results. These simulations should give us indications on which layers of the donor star are actually transferred to the other star as well as how mass is transferred (e.g. accretion disk vs direct impact) and how it settles on the accretor. This work is aimed at getting distinct observational signatures which would help identifying the dominant formation mechanism of blue straggler stars.

The Fraction of Runaway OB Stars in the SMC Field

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Poster n.23

Abstract. Field stars represent a significant fraction (20-30%) of the OB population in galaxies. The fraction of field OB stars that originate from clusters can help probe the dynamical evolution of clusters. Estimates for the percentage of field OB stars that are runaways range from the classical value of $< 20\%$ (Blaauw, 1961) to contemporary results suggesting $> 90\%$ (de Wit, et al., 2005). We obtained Magellan observations on the kinematics of field OB stars in the SMC to examine the line of sight velocities of this population. Using these observations, we will estimate the percentage of field OB stars with runaway velocities. Our results could have implications on the high end of the IMF for both field stars and clusters. Other origins of field OB stars will be discussed.

Tracing Intermediate-Mass Black Holes in the Galactic Centre

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Poster n.24

Abstract. We have developed a new method for post-Newtonian, high-precision integration of stellar systems containing a super-massive black hole (SMBH), splitting the forces on a particle between a dominant central force and perturbations. We used this method to perform fully collisional N-body simulations of inspiralling intermediate-mass black holes (IMBHs) in the centre of the Milky Way.

Our simulations show how IMBHs deplete the central cusp of stars, leaving behind a flatter cusp with slope consistent with what has recently been observed. If an additional IMBH spirals in in such a flat cusp, it will take at least 100 Myr to merge with the central SMBH, thus allowing for direct observation in the near future.

Furthermore, our simulations reveal detailed properties of the hyper-velocity stars (HVSs) created, and how generations of HVSs can be used to trace IMBHs in the Galactic centre. We find that significant rotation of HVSs (which would be evidence for an IMBH) can only be expected among very fast stars ($v > 1000\,\mathrm{km/s}$).

Is our sun a singleton?

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Poster n.25

Abstract. All stars are formed in some form of cluster or association. These environments can have a much higher number density of stars than the field of the Galaxy. Such crowded places are hostile environments: a large fraction of initially-single stars will undergo close encounters with other stars or exchange into binaries. We will describe how such close encounters and exchange encounters will affect the properties of a planetary system around a single star. We define singletons as single stars which have never suffered close encounters with other stars or spent time within a binary system. It may be that planetary systems similar to our own solar system can only survive around singletons. Close encounters or the presence of a stellar companion will perturb the planetary system, often leaving planets on tighter and more eccentric orbits.

NIR spectroscopy of the most massive Galactic star cluster Westerlund 1

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Poster n.26

Abstract.
Young massive extragalactic cluster have presented us with a confusing puzzle: While spectroscopy of individual star clusters leads to the conclusion that most of the targeted clusters have the potential to survive for several Gyr, population studies of large numbers of clusters suggest that as much as 90% of the clusters get destroyed in every decade of time. Since one of the origins for the first result could lie in false assumptions concerning the dynamical state of the extragalactic clusters, we targeted the most massive (around 10^5 $M_\odot$) Galactic young star cluster, Westerlund 1, for a spectroscopic analysis comparable to the one performed for extragalactic clusters (medium resolution NIR spectroscopy using ISAAC/VLT). For this nearby cluster, the advantage is that it is spatially resolved into individual stars. We find no evidence for rapid expansion or collapse, so the assumption of virial equilibrium should not be strongly violated.

On the efficiency of field star capture in star clusters

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Poster n.27

Abstract. One of the most exciting recent findings in investigations of globular cluster systems is that the colour

of individual globular clusters of the blue sub-population is correlated with their luminosity. Brighter globulars are redder. Various mechanisms to explain this finding have been brought forward, such as pressure induced self-enrichment or "sample contamination" by stripped nuclei of dwarf galaxies. Also the capture of field stars in giant elliptical galaxies may in principle cause such colour-magnitude trends. This is because field stars are usually much redder than cluster stars and therefore cause a red-ward change of the integrated cluster colour when captured. In this contribution we investigate the efficiency of field star capture, based on collisional N-body simulations of the gravitational interaction between field stars and cluster stars. We present the results of these calculations for a range of star cluster masses and as a function of environments (i.e. cold disk vs. elliptical galaxy). Is field star capture efficient enough to cause the observed colour-magnitude trends?

GMOS Spectroscopy of Globular Clusters and Nuclei in Dwarf Elliptical Galaxies

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Poster n.28

Abstract. We present result of a Gemini/GMOS program to measure spectroscopic metallicities and ages of globular clusters and nuclei in dwarf elliptical galaxies in the Virgo and Fornax Clusters. Preliminary results indicate that the globular clusters are old and metal-poor, very similar to the globular clusters in the Milky Way halo. The nuclei tend to be more metal-rich than the globular clusters but less metal rich and older, on average, than the stars in the bodies of the galaxies. The [α/Fe] ratio appears to be solar for the globulars, nuclei, and dEs, but the uncertainties do not exclude some globular clusters from being enhanced in alpha elements.

The Relation Between Field Massive Stars and Clusters

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Poster n.29

Abstract. Massive "field" stars are those that appear in apparent isolation, in contrast to those in clusters. Whereas cluster stars are formed together, simultaneously, in large aggregates, field stars have multiple origins. Some massive field stars may be the "tip of the iceberg" on small groups of physically associated stars, while others appear to be "runaway" stars that are dynamically ejected from clusters. What is the intrinsic relation between clusters and field stars, and what is the fraction of runaway stars? Since massive stars are the most luminous stellar population, their demographics are accessible in the nearest external galaxies. We present our current efforts to understand these issues for the Small Magellanic Cloud.

Tidal binary disruptions by massive black holes

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Poster n.30

Abstract. Massive black holes (MBHs) tidally disrupt binary stars passing it on eccentric orbits. After tidal

disruption, one of the binary components is bound to the MBH. We show that high binary disruption rate (induced by massive perturbers or nonaxial potentials) implies a modification of the distribution function of the cusp near the MBH, and strongly affects the stellar dynamics around it. In addition, the increased capture rates have important observational implications for the rate of gravitational wave (GW) events and tidal flares from galactic nuclei. The event rates for GW emission from eccentric and zero eccentricity extreme mass ratio inspirals and GW bursts which could be observed by the Laser Interferometer Space Antenna (LISA) are calculated.

Capture-induced binarity of massive stars in young dense clusters

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Poster n.31

Abstract. Observations show that for massive stars the binary frequency seems to be higher than for lower mass stars in young dense clusters. This suggests that in clusters like the ONC different mechanisms are at work in the formation of high-mass binary or multiple systems than for low-mass stars. We investigate the stellar dynamics in young dense clusters to determine the role of capture in binary formation in high-mass stars. It turns out that in contrast to lower mass stars capture is a frequent process for massive stars. However, this does not neccessarily lead to long lasting binary systems but is often of a more transient nature. Nevertheless, capture processes could account for 15-25% of the observed 'binaries' of the OB-stars (75%) in Orion.

The physical origin of complex stellar populations in compact star clusters

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Poster n.32

Abstract. The observation of non-homogeneous complex stellar populations in some star clusters challenges the current understanding of star formation. Star clusters such as the Orion Nebula cluster or the sigma Orionis cluster have been found to host much older stars than the main bulk of the young stars. Massive star clusters such as Omega Centauri or G1 exhibit a spread of metallicity interpreted as differently old stellar populations with an age spread of a few Gyr. We summarise the current explanations of these complex populations and suggest new physical mechanisms that may naturally account for the observations.

Paucity of Dwarf Nova outbursts in Globular Clusters

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Poster n.33

Abstract. We have conducted an extensive photometric search for dwarf nova (DN) outbursts in 16 Galactic globular clusters (GCs). The survey was based on the rich photometric data collected by the Cluster AgeS Experiment (CASE) team. We have identified two new DNe. Together with previously known systems this gives the total number of 11 known DNe in 7 Galactic GCs. Inserting artificial light curves of "DNe" into frames of

investigated clusters allowed us to assess completeness of the search. Our results clearly show that outbursting cataclysmic variables (CVs) are very rare in GCs in comparison to field CVs where half of the systems belongs to DNe. Recent X-ray observations of GCs lead to identification of hundreds of compact binaries. Many of them are promising candidates for CVs. The theory also predicts that dozens of white/red dwarf binaries should form in GCs via dynamical processes or internal evolution of the binaries. Our results rises the question about possible causes of paucity of outbursts in GCs.

The binary fraction in M4: a MODEST observational project

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Poster n.34

Abstract. We are conducting a multi-instrument observational campaign aimed at deriving the present day binary fraction, and the properties of the binaries in the Galactic globular cluster M4.

We will present the first results from multi-epoch high resolution spectroscopy with FLAMES+GIRAFFE/VLT on 2500 red giant branch and upper main sequence stars.

We have also used ACS/HST images of the central 200×200 arcsec^2 in order to derive the binary fraction, and the binary properties from the color distribution of the stars in the upper 3 magnitudes of the cluster main sequence.

Finally, we will present a pilot project based on adaptive optics NACO observations of the inner core of M4 aimed at the identification of binaries with massive companions on the basis of their wobble around the center of mass.

This project, born within the MODEST collaboration, shall provide fundamental observational inputs for the any future models of M4.

Deep *chandra* Observations of M4: Obtaining a Complete Sample of Primordial Binaries

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Poster n.35

Abstract. Recent *Chandra* work has shown that the active main-sequence binaries in low density clusters are largely primordial, rather than dynamically formed (as the low mass X-ray binaries and bright cataclysmic variables are). Recently, deep *Chandra* observations of M4 have reached the lowest X-ray luminosities yet in a globular cluster. These observations will uncover ∼90% of the active main-sequence binary population. This will constitute the first nearly complete and well-defined sample of primordial binaries in a globular cluster. I will report on the preliminary results from these observations.

The population of Open Clusters in the nearest kpc from the Sun

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Poster n.36

Abstract. For our study of open clusters we used the all-sky catalogue ASCC-2.5 (Kharchenko 2001, CDS Cat.I/280A) with absolute proper motions and B, V magnitudes of 2.5 million stars. The catalogue is complete down to about $V = 11.5$ mag. Screening the ASCC-2.5 resulted in the identification of 520 known clusters and the detection of 130 new ones. Based on combined kinematic-photometric membership criteria, a set of astrophysical parameters (i.e. size, reddening and distance, age, mean proper motion and radial velocity) was obtained for each of the 650 clusters. The cluster sample is complete within a distance of about 1 kpc from the Sun. The data were used to study the population of open clusters in the local Galactic disk by jointly analysing the spatial and kinematic distributions of clusters. We derived parameters of the cluster population such as the local density, the distribution perpendicular to the Galactic plane, the lifetime, and the total number of clusters currently existing in the Galaxy. Fluctuations in the general distribution of clusters in coordinate and velocity space can be explained via the existence of several open cluster complexes of different ages.

XMM-Newton observations of neutron stars and cataclysmic variables in globular clusters

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Poster n.37

Abstract. We have already observed eight Galactic globular clusters with XMM-*Newton* and we have complementary optical, UV and radio data for many of these.

During this presentation, we report on an XMM-Newton observation of the globular cluster NGC 2808. We detect at least one quiescent neutron star low mass X-ray binary of the 2.8 expected, if these systems are formed through encounters, and we show evidence for the presence of 20 to 30 cataclysmic variables in the core, in agreement with the models. Five soft sources are detected within 6 times the half-mass radius of the cluster and some of them are possibly active binaries. We discuss these results with regards to new observations of this cluster with *Chandra*. We also review the specific nature of cataclysmic variables in globular clusters in light of recent VLT observations of a cataclysmic variable in M 22.

Dynamics of Planetary Systems in Star Clusters

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Poster n.38

Abstract. We study the changes of planetary orbits in star clusters due to interactions with stars, using two alternative numerical approaches (direct NBODY and hybrid Monte Carlo) and compare the results with existing analytical models. The results are presented as a series of numerical simulations which are designed to investigate the influence of stellar encounters on the dynamics of extrasolar planets with a wide variety of orbital properties, such as e.g. changes of eccentricities, semi-major axis and inclinations. The consequences for the existence of bound and free planets in star clusters are discussed.

Tidal Radii and Masses of Galactic Open Clusters

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Poster n.39

Abstract. For more than 200 out of 650 Galactic open clusters identified in the ASCC-2.5 catalogue, we determine tidal radii from a three-parameter fit of King's profiles to the observed integrated density distribution of cluster members. The results are used to calibrate the observed sizes of the remaining clusters to a uniform scale of tidal radii of open clusters in the Solar neighbourhood. For each cluster the tidal mass is computed from the tidal radius. Taking into account that our cluster sample is complete to a distance of about 1 kpc, we construct the mass functions for clusters of different ages. A comparison of the mass functions of younger and older clusters gives observational constraints on the formation and destruction of open clusters.

Star formation in young star cluster NGC 1893

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Poster n.40

Abstract. We present a comprehensive multi-wavelength study of the star-forming region NGC 1893 to explore the effects of massive stars on low-mass star formation. Using near-infrared colours, slitless spectroscopy and narrow-band $H\alpha$ photometry in the c luster region we have identified candidate young stellar objects (YSOs) distributed in a pattern from the cluster to one of t he nearby nebulae Sim 129. The $V, (V-I)$ colour-magnitude diagram of the YSOs indicates that majority of these objects have age between 1 Myr to 5 Myr indicating an age

spread in the star formation in the cluster. The slope of the KLF for the cluste r is estimated to be 0.34 ± 0.07, which agrees well with the average value (~ 0.4) reported for young clusters. For the entire observed mass range $0.6 < M/M_{\odot} \leqslant 17.7$ the value of the slope of the initial mass function, 'Γ', comes out to be -1.27 ± 0.08, which is in agreement with the Salpeter value of -1.35 in the solar neighborhood. However, the value of 'Γ′ for PMS phase stars (mass range $0.6 < M/M_{\odot} \leqslant 2.0$) is found to be -0.92 ± 0.09 whi ch is shallower than the value (-1.71 ± 0.20) obtained for MS stars having mass range $2.5 < M/M_{\odot} \leqslant 17.7$ indicating a break in the slope of the ma ss function at $\sim 2M_{\odot}$. Estimated ′Γ′ values indicate an effect of mass segregation for main-sequence stars, in the sense that massive stars are preferentially located towards the cluster center. The estimated dynamical evolution time is found to be greater than the age of the cluster, therefore the observed mass segregation in the cluster may be the imprin t of the star formation process. There is evidence for triggered star formation in the region, which seems to govern initial morphology of the cluster. The circumstellar disc half-life time is found to be ~ 2 Myr which is consistent with the va lue (3 Myr) suggested by Haisch, Lada & Lada (2001).

Ionisation in binary-binary scattering

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oral

Poster n.41

Abstract. Encounters between binary stars and single stars and between binary stars and other binary stars play a key role in the dynamics of dense stellar systems. In the simple model, in which stars are approximated by point masses, a number of theoretical and numerical results are known. In particular there exist relationships to help to describe the destruction process of binary stars (ionisation) through three-body encounters between binary and single stars. Here we extend these results to the four-body case involving encounters between pairs of binary stars that lead to a disruption of the binaries into single stars.

On the reliability of average lifetime calculations for the 3-body problem

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Poster n.42

Abstract.

Numerical solutions for the 3-Body Problem can be extremely sensitive to small errors. We consider how small errors in calculations can effect the lifetime of these systems. In particular, we show that numerical errors cause the average lifetime of a 3-body system to be shorter. Using the Sitnikov Problem as an example, we show numerically that errors can cause the average lifetime of the problem to be shorter. To give a theoretical explanation of this, we construct an approximate Poincaré map for this problem and delineate the structure of the escape regions. We show that numerical errors can destroy escape regions and cause orbits to migrate to a region in which escape is faster.

Embryo to Ashes - A stellar evolution code for calculating complete evolutionary tracks, hands-off.

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Poster n.43

Abstract. We present a new stellar evolution code and a set of results, showing its capability to calculate full evolutionary tracks for a wide range of masses and metalicities. The code is meant to be used also in the context of modeling the evolution of dense stellar systems, for performing on-line evolutionary calculations for 'non-canonical' (i.e. merger-products) stellar configurations. For such tasks, it has to be robust and efficient, capable to run through all phases of stellar evolution without interruption or intervention. The code is based on the original scheme introduced by Eggleton in the early 1970 Rs, to which various modifications and adjustments have been made. It is modular and versatile, including up-to-date input physics and a choice of recipes by which various processes can be treated. Here we show evolutionary tracks for Populations I and II, and masses in the range 0.25 V 64 Msun; a calibration solar model, fitting the characteristics of the present sun to an accuracy of 1evolutionary results of a 1 Msun model for a wide range of metalicities, and a first go at evolving non-canonical configurations V the outcomes of MS-MS mergers.

High-resolution images of the centers of dense young clusters: an observational census of the number density of massive stars

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Poster n.44

Abstract. I will present high-angular resolution images (speckle, AO, and HST) of the centers of a number of young stellar clusters, including the Trapezium Cluster in Orion and some galactic and extragalactic star burst clusters (e.g. NGC 3603, Westerlund 1, Arches; R136, NGC 346). The density of massive stars in these cluster centers will be given, in order to estimate the time for stellar collisions. The location of the most massive spectroscopic binaries near the centers of these clusters will also be discussed, with an eye on the question of mass segregation at birth.
